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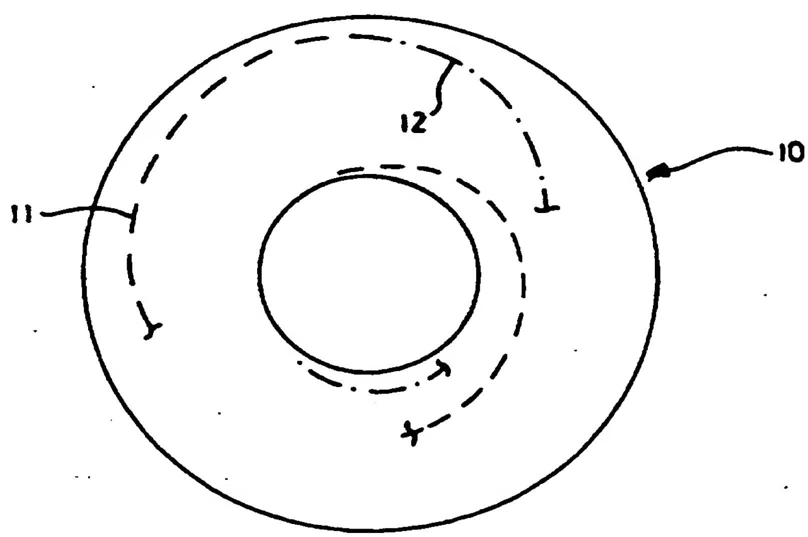
(57) Abstract

An optical data carrier has a pair of spiral tracks of opposite hand that may be read either sequentially or simultaneously. When read simultaneously, the information is recorded at a uniform spatial density and demodulated into a common data stream. The heads reading the tracks are equidistant from a median radius and move along the carrier at a constant radial rate to provide a substantially uniform combined data rate.



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MULTIPLE-LAYER OPTICAL DISC AND APPARATUS

Conventional compact disc technology has become the dominant form of optical disc recording in the marketplace for audio discs, Read-Only-Memory data discs ("CD ROM"), and various interactive data systems including computer and video games. However, it has been hampered in the field of video recordings because the 650 Mega Bytes of data which can be stored on a single CD is approximately half of the approximately 1.2 to 1.3 Giga Bytes of data which is required to store a feature length movie using conventional data compression technologies such as MPEG-1. (MPEG stands for "Motion Pictures Experts Group" and is an ISO standard for video compression.)

This invention is designed to overcome the limitations of data capacity encountered with conventional CD technology by means of a multiple layered disc and a player employing an optical read head.

In general terms, the present invention provides an optical data carrier having information encoded in a pair of spiral tracks. The tracks are separated from one another along the optical axis of the carrier and the spirals are of opposite hand.

In one preferred embodiment, an optical head may focus selectively upon one of the tracks and can switch between tracks without interrupting data flow by buffering the data. Accordingly, the information in the tracks may be read consecutively without interruption.

In an alternative embodiment, a pair of heads may be offset from a median radius and read respective tracks at an average data rate corresponding to the median radius.

Embodiments of the invention will now be described by way of example only with reference to the accompanying drawings in which:

Figure 1 is a schematic representation of the components of an optical data carrier;

Figure 2 is a plan view of the carrier of Figure 1;

Figure 3 is a schematic representation of an alternative embodiment of data carrier and its use in a multiple head system;

Figure 4 is a schematic representation of a multiple head system similar to Figure 3 but without separate timing tracks;

Figure 5 is a block diagram at a phase locked loop used with the embodiment of Figure 4;

Figure 6 is a block diagram of an alternative phase locked loop to that shown in Figure 5;

Figure 7 is a flow diagram of the operation of the phase locked loop of Figure 6; and

Figure 8 is a timing chart showing the output of the PLL of Figure 6.

As illustrated in Figure 1, an optical data carrier 10 is formed from a pair of optical discs 1, 8. The optical disc 1 may be formed to conventional standards, either by being uniquely recorded or by being formed by injection moulding. The disc 1 has a transparent substrate 2 with a data surface 3 formed with a plurality of marks representative of information and arranged in a spiral track 11. The surface 3 is coated with a reflective layer 4 upon which a scanning laser spot (not shown) can be focused in order to read the information in the various manners known to prior art.

Preferentially, the marked data surface 3 is of the weak diffraction grating type composed of a plurality of marks of a depth one-quarter that of the wavelength of the scanning laser spot, as is the case with mass produced CD's, for example. However, other marking schemes known in the art may be utilised.

A second disc 8, (shown upside down) is substantially identical in construction to the first disc 1, having a marked data surface 6 bearing different data to that of surface 3 in spiral track 12, a substrate 7 and a reflective layer 5.

The discs 1,8 are bonded together by a transparent bonding layer 9 of sufficient thickness that when a spot is formed by a lens 13 of an optical head 14 of, preferentially a numerical aperture of 4.5 to 5 on one of the data surfaces 3,6, the light incident on the other data surface is defocused enough that the marks on the other layer do not interfere with the read-out of the data layer which is in focus. The transparent bonding layer 9 may be a plastic, for example, polyvinyl alcohol.

Preferentially, both disc substrates 2,7 can be made in the conventional injection moulding machines employed to manufacture CD's. However, provision must be made to make the reflective layer 4 semi-transparent. A semi-transparent metal layer of gold or aluminum can be deposited on the substrate by various means including vapour deposition and magnetron sputtering. It is also possible to apply semi-transparent organic dye layers (for example, silicon napthalocyanine) by means of known spin coating techniques.

Whichever film is applied to form the semi-transparent/reflective layer 4, it should be one which can withstand the transmission of light from the read-out laser which is powerful enough to pass through substrate 2, semi-transparent/reflective layer 4, and transparent bonding layer 9 to reflect off the reflective layer 6 on the bottom disc 8, and pass through the layers on the return path to the photodiodes of head 14 for data readout. While the degree to which the spot is defocused with respect to the upper layer when the lower layer is being read effectively reduces the energy delivered to the semi- transparent/reflective layer, there will inevitably be instances when the operation of the focus servo-system permits the power level required for reading the lower layer to be focused on the upper layer. With this in mind, gold is preferred as the material forming the semi- transparent/reflective layer because of its exceptionally high reflectivity in the preferred

wavelengths, its comparative durability with respect to the energy levels encountered and the facility with which it can be deposited as an exceptionally thin film.

With respect to the reflective film 5 on the lower disc, this layer must be formed of a highly reflective material which preserves the marking features of the marked surface 6. Here again, gold is preferred for its exceptional reflectivity and its properties with respect to the formation of thin films.

The upper disc 1 may be formed as a conventional constant linear velocity (CLV) disc such as those formed for CD-Audio, CD-ROM and CD-I discs, i.e. they have a uniform spacial density of information. Typically such CLV discs are formed as a spiral track of pits which in turn are formed so that a laser spot focused on the interface between the marked data surface and the reflective film produces a read-back signal which can be adequately demodulated as the track 11 is scanned from the innermost radius to the outermost radius with the record rotating in a given direction. Each mark representing information is of uniform track length and the rotational speed of the disc is modulated as the track is scanned to maintain a substantially uniform linear velocity.

The track 12 on surface 6 of lower disc 8 is formed with the same spiral pitch as that of track 11. However, the spiral track 12 carrying the information is of opposite hand to the track 11 on the surface 3 so that, with the record rotating in the same given direction, a laser following its pitch will transit automatically from an outer radius to an inner radius. This reversal of radial tracking direction means that the tracks 11,12 may be played consecutively by simply changing the focus of the read head 14. Therefore, with minimal buffering to allow for changing the focus from one layer to the other and the acquisition of the new track, playback can be uninterrupted.

The optical head 14 for reading such a multiple layer disc sandwich may be a conventional Read-Only optical head such as those employed for CD and LaserVision players and incorporates tracking and focusing mechanisms. Provision is made for changing the focus from one track to the other. This may be a mechanism capable of moving the entire head assembly up and down along the axis of rotation in order to acquire focus on each layer in turn. However, as such a device would not readily detect whether it had been displaced from one surface to the other by a vibration, etc. it is preferred that the optical head incorporate an additional beam splitter and read-back photodiode array (not shown) each of which can be disposed in the manner well known in the prior art to focus at different specified levels. In the case of astigmatic focus systems this would require two cylindrical lenses to be deployed as well and other known focus servo-systems would require one or more modification so that a correct focus servo exists for each level.

In this manner, the magnitude and direction of any skipping can be readily detected and the shift in focus required to read the different layers can be effected by simply selecting one or the other photodiode arrays as reference.

In operation therefore, head 14 is positioned to one side of the data carrier adjacent the radial inner extent of track 11 and, upon rotation of the carrier 10, reads information from the carrier. The spiral track 11 carries the head radially outward until it reaches the radially outer limit. The head 14 is refocused on the track 12 and proceeds radially inwardly. The buffering of information prevents any interruption of data as the head is refocused.

This system can be employed for recording operations on two or more layers by employing write optical heads modified to focus on different layers and

by using optical film which is semi-transparent, reflective and absorbent (such as silicon napthalocyanine dye) which has been characterized to have the appropriate mix of those characteristics and provided that the disc layers are appropriately spaced so as to avoid inadvertent marking of upper layers when writing lower layers.

It is also possible to provide further pairs of tracks 11,12 and hence to produce a disc sandwich with as many as 10-12 layers. However, as the number of layers increases it becomes increasingly important that two sided recording operations be employed in recordable systems in order to avoid inadvertent marking of the outermost layers.

A further embodiment utilising a double sided disk is shown in Figure 3 where like components will be identified with like reference numerals with a suffix "a" added for clarity.

In the embodiment of Figure 3, the disk 10a has a spiral track 11a on the surface 3a and a spiral track 12a on the surface 6a. The tracks 11a,12a are of opposite hand so as to cause opposite translation of a tracking optical head for a given rotation of the disk 10a. Each of the layers 4a,5a are formed from highly reflective material and the bonding layer 9 can similarly be non-transmissive.

A pair of optical heads 16,17 are located on opposite sides of the carrier 10a. Each of the heads 16,17 is similar in construction and has a pair of optical pick-ups 18,19 facing in opposite directions. One of the pick-ups 18 is directed toward the respective one of the surfaces 3,6 and the other of the pick-ups 19 is directed toward a pseudoclock track 20,22. The pseudoclock track 20,22 is concentric with the axis of rotation of the carrier 10a and is of a form shown in prior U.S. Patent No. 5,303,215 to provide a timing signal to demodulate data read from the tracks 11a,12a.

The data in the tracks 11a,12a is recorded with a uniform spatial density, e.g. a CLV data, although the disc 10a is rotated at a constant angular velocity. As the local linear velocity varies in proportion, the pseudoclock tracks 20,22 provide a timing pattern at each radius to permit the recovered data pattern to be demodulated. It will be appreciated that each of the optical pick-ups 18,19 include focusing elements and tracking actuators as is conventional. Similarly, the tracks 20,22 may be used to modulate a signal if the apparatus is used to record data as well as retrieve data.

The arrangement shown in Figure 3 may be used to provide extended play periods as described above by switching between the tracks and playing each track in succession. However, by providing a pair of optical pick-ups 16,17, it is possible to enhance the data transfer rate.

The carrier 10a is rotated with a constant angular velocity although the data in tracks 11a,12a are recorded with a constant linear velocity. The timing tracks 20,22 provide timing signals for recovery of information as it is read from the respective tracks. The optical heads 15,16 are located at opposite extremes of their respective spirals, that is one is radially innermost and the other is radially outermost and the carrier 10a rotated with constant angular velocity.

For each revolution of the carrier, the radially inner spiral will provide relatively small amount of data due to the minimum length covered by the track whereas the radially outer track will provide a significantly greater amount of information. The two data streams may therefore be combined to provide a data transfer rate that is the sum of the outer and inner tracks.

As the optical pick-ups 20,22 move radially across the carrier 10a, the amount of data recovered in each revolution will increase for the track 11a and

decrease for the track 12a but the net average remains substantially constant. In any given scanning period, the track scanned by the pair of counter translating heads will remain substantially constant with a fixed rotational speed.

The respective pseudoclocks provided by tracks 20,22 may be employed to demodulate data marks of uniform channel bit length despite the variations in local linear scanning speed encountered by each head. The sum of the transfer rates from the two heads remains constant with the two demodulated data streams being interleaved as appropriate to reconstruct the original signal.

Accordingly, relatively high data transfer rates may be obtained without resorting to excessive rotational speeds for the carrier 10a leading to benefits in the design and operation of tracking and focusing elements in the optical heads.

It will be apparent that the use of the double sided carrier 10a shown in Figure 3 provides the opportunity to enhance the data transfer rate by reading simultaneously from opposite sides of the disk or may be used independently to retrieve independent streams of data to serve multiple applications. In each case, the provision of the timing track 20,22 permits demodulation of the recovered data.

Multiple optical heads may be utilized on each side of the carrier 10a, each interrogating an independent portion of the track by circumferentially spacing the heads about the carrier.

Where heads are paired to one another for simultaneous reading, the rotational speed may be adjusted to provide the mean between the two radial placements of the heads thereby maintaining the maximum data rate without imposing undue operating criteria on the optical heads.

As exemplified in Figures 1 and 2, it is possible to fabricate multiple layer discs which are

formed so that two or more layers are at different optical depths which can be scanned from the said side. A disc embodying this feature may be used with the embodiment of Figure 3 so that two or more read or write heads are disposed on the same side of the disc with provision made for the lens actuators and associated controls to focus on the appropriate layers for simultaneous reading. This embodiment is effectively identical to the use of counter-translating heads on two sides of the disc and at least one layer allows sufficient transmission to permit simultaneous scanning.

This embodiment can be applied simultaneously from both sides of a disc with four or more layers. This has the benefit of increasing the total data storage capacity and by facilitating the positioning of more heads increasing the total data rate and/or the flexibility with which users may be assigned use of individual pairs of heads for independent access to the data stored on the disc.

This multiple layer counter-translation architecture can also be applied to the formation of counter-translating timing tracks which can be used as referents.

The data carrier 10 may be used in an embodiment which does not require the use of timing tracks 20,22 for modulation and demodulation as shown schematically on Figure 4. Like components will be identified with like reference numerals with a suffix 'b' added for clarity.

As noted earlier, the tracks 11b,12b are recorded with a uniform spatial density and are arranged on opposite sides of the carrier 10b with an opposite hand. As such, the combined data rate of the two tracks 11b,12b being scanned in a manner which includes counter translation is constant. A crystal clock 28 is used as a reference in this embodiment as a means of producing an acceptably precise constant angular velocity of the

carrier 10b. This may be accomplished by comparing the signal derived from a rotary encoder 30 mounted on the shaft 32 or incorporated into the disc 10b with the crystal clock frequency.

Once the clock and rotation rate have been suitably synchronized, the two heads 16b,17b may be addressed to correlated tracks located at appropriate radii. The correlated tracks are offset equally from a median radius r_m so that as data is read, a constant data rate is maintained by combining the output of the two heads. The heads 16b,17b are positioned by the operation of radial translation servo-systems associated with each of the heads 16b,17b. These servo-systems are known to prior art and may include micrositches for the approximate detection of position and may also involve linear encoders for precise position information. Alternatively, the position of the heads 16b,17b may be determined by counting the tracks on the disc 10a employing techniques known to prior art as "zero-cross" detection, where the peaks of a signal may be counted as the optical heads pass from a reference position to the target track location. Once the position of the heads on the tracks is known, it can then be tracked and read as follows.

In a CLV-type (Constant Linear Velocity) data track, data is stored as a uniform function of track length, i.e. a uniform spatial density. Data frames and channel bits consume the same linear track length at the inner diameter of the data area on the disc as at the outside edge. The rotation rate of the carrier 10b is specified as a Constant Angular Velocity (CAV) which is defined by the specified data rate. This data rate may be specified as twice the data rate of a single head scanning the track between the outer and inner diameters of the data area and indicated at radius r_m. The crystal clock 28 is set to the sum of data recovered from two such tracks. The output of each VCO 34 is thus summed at

summing function 36 and the output compared to the clock output 28 in comparitor 38. An error signal is provided to controls 40 associated with the heads 16b,17b which also receive input from the position encoders associated with the heads 16b,17b. The output of each of VCOs 34 may thus be adjusted to demodulate the data at the radius of the track.

As a CLV-type data pattern employs by definition a uniform linear rate (spatial frequency), the relationship between track length scanned and data rate is uniform. At any given radius, the track length scanned, the number of channel bits scanned and the local data rate are a function of the length of one turn of the spiral at that radius. Therefore, when such a disc is turned at a constant angular velocity, the channel bit frequency of any given track pattern will similarly be proportional to its radius.

As the median track at radius r_m is co-ordinated with the crystal clock, the spatial frequency sf_m of the channel bits scanned during one rotation will remain uniform. Similarly, at any given radius r_1 which is different from r_m the local spatial frequency sf_1 will also remain uniform and sf_1 will be proportional to sf_m as r_1 is proportional to r_m because the spatial frequency is a function of the scanned track length.

With this in mind, it is clear that if the radius can be measured, known or calculated, it is possible to determine an approximate spatial frequency and to set the frequency of a Voltage Controlled Oscillator (VCO) 34 associated with the readout of respective tracks appropriately.

In order to maintain synchronization, the features of the data structure are utilized. The data recorded in the track includes synchronizing marks which are typically recognizable as run-length variations when scanned and the entire data pattern is formed in reference to the spatial frequency in such a way that

each pit edge (or transition of any kind from one mark type to another) corresponds to the position of one channel bit.

As the data is scanned, a circuit can count the number of cycles of respective VCO's 34 between transitions which demarcate data marks. In this manner, the synchronizing marks can be quickly identified. As the synchronizing marks are repeated at a known spatial frequency within a given data structure, it is possible to further match the scanned frequency in the data with that of VCO 34 by speeding up or slowing down the frequency of VCO 34 until the VCO frequency matches the specified spatial frequency. In some configurations, it may be desirable to also count the number of cycles between synchronizing marks.

Synchronization of the frequency of VCO 34 with that of the scanned data is then preferentially controlled by a phase-locked loop which matches all of the scanned data edges from any and all marks to the VCO 34 by adjusting the VCO frequency. When this is done at the two correlated radial locations (which for example match a "slow" track to a "fast" track), the summed spatial frequencies equal the summed local channel bit rates. This is equal to the summed VCO frequencies and each sum equals the frequency of the crystal clock 28.

Such synchronization is sufficient to extract track numbers encoded in the sub-coding data blocks which follows each synchronizing mark. Once such addresses are determined, it can be assured that the two counter-translating heads 16b,17b are addressing the correct addresses, i.e. tracks that are equally offset from the median track r_m.

Ordinarily, it would not be possible to reliably track the changing data rates of two such spiral tracks formed to uniform spatial frequency standards under these circumstances because the local VCO frequencies would either drift, if the reference became

too loose, or would be subject to fluctuation in the normal course of tracking erroneous data from potentially damaged or obscured surfaces, etc. However, because of the relationship of the two heads 16b,17b, the summing of the two frequencies of data streams to the crystal clock 28 provides a reference which may be used to stabilize the local VCO frequencies within acceptable operating tolerances as will be described in further detail below.

In this manner, the data marks at each corresponding radius may be measured by reference to the local phase-locked VCO frequency, the bit count can be matched to data mark lengths, and the two signals so derived may be combined and delivered as a pulse code modulation which is modulated by the crystal clock rate and which may in turn be demodulated in the manner well known to prior art.

It should be noted than any suitably precise means employed for synchronizing an oscillator with a signal may be employed and these include but are not limited to a number of techniques and circuits employed in radio and television modulation and demodulation and may also include the use of digital signal processors of suitable resolution to measure the frequencies by techniques such as Fast Fourier Transform, wavelet scalograms or, via fractal based vector recurrent iterated functions. In short, all such techniques for measuring and summing the locally scanned spatial frequencies are contemplated here and any means for summing such frequencies and comparing them to a reference frequency during operation is contemplated as well.

It is also possible to record data without a separate timing rack by resorting to recordable discs which have been provided with any suitable recording film or structure. Such discs require pre-formatting patterns with effectively serve as servo-system referents to identify track number and/or spatial frequency so that

the operating system may make appropriate marks at the appropriate location. Such formatting marks on the disc must also correspond to the distributed data pattern to be recorded. Such formatting marks may be formed so that they present a contrast with the pattern of the data marks to be written. Examples of such patterns can include the use of phase pits as sampled-servo reference marks for discs which employ magneto-optical recording films. Similarly, the contrast may be based on frequency separation in the manner that so-called "wobble-groove" tracks can be used to guide the formation of a data recording on a recordable compact disc as a detectable pattern in the tracking signal which can be ignored by ordinary players. Similarly, it is possible to employ so-called "white writing" media (such as Indium Antimonide) for the data marks and phase pits as formatting patterns. It is also possible to employ spatial formatting in the manner of sampled servo-systems. It is also possible to use a combination of pits which have been formed in the mutually adjacent areas between the areas which will record the tracks as formatting marks.

In such recording operations, the machine must synchronize the VCO's 34 to their respective radial addresses, sum the frequencies and make reference to a clock 28 in a manner substantially similar to, if somewhat more precise, than that described above for use in read-only operations. The frequencies thus derived are used to control the operation of a write pulse circuit. Provision should be made to operate the write pulse circuit at a rate which is high enough to effectively mark at the fastest linear velocity encountered at the outermost track of the data area. Pulses of such a duration will make identical marks at all slower scanning rates. The timing frequency then is strictly to provide a triggering function for this pulse.

Alternatively, once the relative frequency rate of any given spiral turn has been detected, that can be compared to the system clock standard as a component of a laser power control circuit which can adjust laser power automatically to compensate for local track velocity during recording operations.

In the above embodiment, the measured radius of each head 16b,17b is used to factor the master clock and provide a nominal bit clock speed at the location of the head. Thereafter, the data structure is used to fine-tune the VCO 34 with the sum of the channel bits from each head used to verify the retrieval.

A similar approach may be used in which the statistical distribution of channel bits is utilized to provide an initial setting for the VCO 34 with data clocking subsequently synchronizing the VCO 34.

The circuit used to derive the initial setting of the VCO 34 is a conventional PLL and is driven by a frequency F_{in} corresponding to 588 times the frequency F_{out} at which the sync marks appear, there being 588 channel bits per frame for a conventional CD structure. This frequency is proportional to the instantaneous velocity of the disc under the lens.

Assuming that the pits on the data track are close to randomly distributed, which simple observation suggests, then the number of transitions per unit length tends to a constant.

Each transition is converted to a short (typically up to 3 channel bits) pulse with a simple monostable, and the pulses averaged with a capacitor. The voltage obtained represents the count of transitions per unit time, and therefore the track length/time, also known as velocity. This signal may then be used as an input for the VCO that drives the PLL.

Thus, the PLL can be implemented as a narrow-range PLL circuit with an adjustable centre frequency. The control software can accurately calculate the initial

operating frequency of the PLL either from the radius signal or from sampling the data, and then slowly adjust this as the disc plays to compensate for the gradual change in linear data density, and for spindle speed variations.

Two approaches to the PLL design may be used. The first is a Digital PLL (DPLL) and the second is an Analog PLL with adjustable center frequency.

The Analog PLL shown in Figure 5 has a range input which is adjusted by control software via Digital to Analog Convertor. For initialization, a loop defeat switch removes the feedback of the inner loop, and a frequency measurement circuit allows the controller to establish a desired initial center frequency. After initialization, a "current error" filter provides an indication as to whether the circuit is running above or below the center frequency set by the range input, and the controller can adjust the range input accordingly.

The DPLL circuit shown in Figure 6 is driven by a "Master Clock" at 10 times the current center frequency. It analyses the EFM signal and produces an EFM signal and a clock, which together represent a recovered data signal. The DPLL also provides an indication as to whether the data's rate is higher or lower than the rate of the master clock. The DPLL can tolerate errors in the master clock frequency of up to 5%. The control software is responsible for adjusting the master clock to keep it within these limits.

Referring therefore to Figure 5, the basic inner loop resembles a conventional PLL design. A phase comparator 50 measures phase errors between the clock edges fed from VCO 34 and edges on the EFM input derived from the optical heads 16,17. These errors are integrated in the Loop Filter 54 to form the control signal for the Voltage Controlled Oscillator (VCO) 34. The design of the VCO 34 is such that the "Control" input

can only produce small changes in output frequency, about +/- 10%.

In order for the inner loop to operate properly, the range of frequencies available to the VCO 34 must be roughly centered about the current operating frequency - which is the channel bit rate of the incoming EFM signal. The "Range" input 56 to the VCO 34 is set by the controller to achieve this centering. This is done in two stages, initialization and tracking, as described below.

Initialization

The initialization operation is performed whenever the system is to start reading data at a new radius. The controller calculates the EFM signal's rate based on the disc's current rotation rate, determined by encoder, and the radius of the optical heads 16,17 as provided by the position sensors associated with each head. The controller then proceeds to "center" the VCO 34 at this frequency as follows:

1. The controller activates the "Loop Disable" signal 58. This effectively zeros the control input to the VCO 34 and in so doing breaks the inner control loop. The output of the VCO 34 is now at the VCO's center frequency.
2. The controller uses a frequency counter 58 to measure the VCO's center frequency.
3. The controller compares the measured frequency to the desired frequency determined by the estimated EFM signal rate.
4. Steps 2 and 3 are repeated until the center frequency is sufficiently accurate.
5. The Analog to Digital conversion 60 is read. This provides a zero reference to the "Centering Error" signal.

6. With EFM input data available, the controller deactivates the "Loop Disable" signal 58.

The inner loop will now proceed to track the EFM signal as long as the frequency of that signal remains relatively constant.

Tracking

As the EFM's signal rate begins to change (due to change of radius or change of spindle rotation rate), the inner PLL will track this change but will become uncentered. This condition is reflected by a DC offset in the VCO control signal. A low-pass filter 62 extracts this DC offset and presents it to the Analog-to-Digital converter so that it may be read by the controller.

The controller compares the value read from the Analog-to-Digital converter to the zero-reference value which it established during the initialization phase. If the values are significantly different, the PLL has become uncentered. The controller then writes a new value to the Analog-to-Digital converter to adjust the PLL range input. The filter 64 on the Range signal 56 prevents high rates of change on the VCO Range input, which would disturb the stability of the inner loop.

Loop Filter Frequency Adjustment

It may not be possible to design a loop filter which can stabilize the inner loop across the entire 2.5:1 operating range of the circuit anticipated. The filter 64 can contain analog switches which modify its response. The operating range can be divided into "zones", and the controller then sets these switches according to the current zone of operation.

Accordingly, once the initial EFM bit rate has been estimated either by the position sensors or by analyzing the data structure, the VCO 34 can maintain

synchronization to provide demodulated bit streams at a constant clock rate.

A block diagram showing the digital phase-locked loop is shown schematically at Figure 6 and in further detail in Figure 7. The EFM signal from the carrier 10b is sampled at 10 times nominal channel bit rate and the circuit shown in the block diagram of Figure 6 is a synchronous state engine which runs at 1.25 times the nominal rate.

Edge Detector

An external synthesizer 70 runs at 10 times nominal rate and drives a transition detector 72 which samples the EFM signal on each clock. Every 9 clocks, this detector 72 provides an input to digital PLL Core 74 indicating

1. whether a transition occurred on the EFM signal in the previous 8 clocks;
2. if so, the edge number (0-7) on which it occurred.

Current Time and Current Rate Registers

The PLL Core circuit 74 shown in Figure 7 contains a "Current Rate Register" 76 and a "Current time Register" 78. The Current Time Register 78 is 11 bits wide; it has a fixed-point fractional format with 5 integer bits and 6 fractional bits. On each clock edge, the Current Time Register indicates the assumed phase of the EFM input signal, in channel bits. For instance, if the system clock is at its correct nominal rate, each 1.25x clock cycle corresponds to 0.8 channel bits. In this case, the "Current Time Register" will increase by 0.8 on each clock cycle. In integer terms, this is rounded: (0.8 x 64) is about 51. The Current Rate Register 76 stores the number which is added to the Current Time on each clock. As the external signal

changes speed relative to the 1.25x clock, the Current Rate is adjusted so that the Current Time correctly tracks these changes. The Current Time is allowed to overflow so that the value it stores is actually MOD 32 EFM clocks.

Event Span Calculation

Whenever the external circuit detects a transition by detector 72, the circuit calculates the number of channel bits which have elapsed since the previous transition. First, the 3-bit offset associated with the transition is converted to a time offset in terms of channel bits. This is done by multiplying it by the current rate (the 3-bit number is assumed to be a fraction from 0/8 to 7/8 for this purpose). The resulting produce is added at 80 to the contents of the Current Time Register. The result is the time of the transition in terms of the internal Current Time, and is called the "Current Event Position" indicated at 82.

A register 84 (Previous Event Position) stores the time of the previous transition; this is subtracted from the Current Event Position 82. The result is the time span from the previous edge to the current edge, corrected according to the current rate, and represented in a fixed-point format with 6 fractional bits. This is called the Event Time Span indicated at 86.

Event Span Quantization

Each time an Event Time Span is calculated, it is quantized to an integer number of clocks. For instance, a pulse in the EFM signal corresponding to 4 channel bits may result in an Event Span of 250. This represents 3 + 58/64 or 4 full clocks less 4/64 of a clock. A quantizer circuit 88 identifies this as a 4-clock event with an error or -4/64. This is done by a simple binary rounding operation. The integer part of the rounding operation is passed to the output sequencer;

the fractional error (which will be the range of +/-0.5) is passed to the feedback circuit.

Feedback Circuit

The error signal from the quantizer 88 is used in two ways. First of all, it modifies the value loaded into the Previous Event Position register 84. If the error was 0, the Previous Event Position register 84 will simply be loaded with the Current Event Position to serve as a reference for the next transition. If there is an error, this error is multiplied by a scale factor and subtracted from the Current Event Position to obtain the update value for Previous Event Position. The resulting value is a linear combination of the current transition's measured time (Current Event Position) and its "expected" time (Current Event Position - Quantizer Error). This mechanism allows the circuit to be more insensitive to errors in the positions of individual edges.

The Quantizer error is also fed into a digital filter circuit 86 which applies corrections to the Current Rate Register 76. This allows the circuit to track changes in the rate of the incoming EFM stream. The Current Rate Register 76 is clipped to a lower limit of 51-7 and an upper limit of 51+8, to prevent error bursts from inducing invalid "Current Rate" values.

The parameters of the error feedback circuit are adjusted to obtain good tracking of the EFM signal under all input conditions.

Output Sequencer

The output sequencer 90 receives events from the Quantizer 88 and recreates the EFM signal in a synchronous manner. For instance, if the quantizer identifies a 3-clock event, then a 4-clock event, then a 5-clock event, the output sequencer may output low data for 3 clocks, high data for the next four, and low data for the next 5. Since the DPLL is operating at 1.25x

frequency, these events will take place over a time of about 1.25 (3 + 4 + 5) or 15 clocks. The exact number will vary but the number of pulses to be output on the "Output Clock" pin will usually be less than the number of 1.25X clock cycles during which they are generated. The Output Sequencer 90 therefore generates idle cycles (no pulse) on the Output Clock Line occasionally. The EFM decoder which receives these signals from the DPLL must be able to tolerate this condition. The 3/4/5 example is shown in Figure 8.

Dummy Event Generator

EFM coding does not allow more than 11 Channel Bit clocks between edges. The mod-32 "Current Time Register" will operate satisfactorily if this condition is met. However, under error conditions and non-tracking condition, long periods of time (>32 EFM clocks) may pass with no transitions.

The Dummy Event Generator 92 monitors the input and inserts a Dummy Event when 16 clocks pass without a transition. The Dummy Event passes through to the Output Sequencer, where it generates clocks but no transition on the data. This allows the EFM decoder (which receives the output of the DPLL) to be continually clocked during such errors.

Cumulative Error Calculator

The Cumulative Error Calculator counts the number of times that the Current Time register overflows; effectively it implements a 7-bit extension to the Current Time Register. If the DPLL is running exactly at its nominal rate of 1.25x the EFM rate, this count will wrap (overflow) every 5120 cycles of the 1.25X clock. The circuit latches the 7-bit count every 5120 cycles and interrupts the controlling microprocessor which reads the count. The processor can analyze this value to see if the DPLL is running above, below, or at the correct

nominal rate for the incoming EFM stream. If the operating frequency is in error, the microcomputer adjusts the frequency of the 10x DPLL clock accordingly.

When the frequency is correct, the value of the latch will be the same on each interrupt. When the frequency is correct, the value of the latch will be the same on each interrupt. When the frequency is high, the Current Rate register will be lower to compensate, and the 7-bit count will count by less than 128 in the 5120 cycle period. It will thus appear to be smaller on each interrupt, wrapping when it reaches zero. The situation reverses when the clock is too slow.

For instance, if the value read on one interrupt is 5 greater than the value read on the previous interrupt, it indicates that the DPLL clock is slow, and needs to be increased by a factor of (128+5)/128.

This measurement averages the Current Rate Register over a long period of time and thus is a very accurate representation of the DPLL's operating frequency error.

It will be apparent from the above embodiments that a double sided disc with opposite handed tracks provides an enhanced data transfer rate. This capability may be used to advantage in a number of applications.

There is a requirement, especially for the delivery of movies on demand in the emerging cable and telephone network markets, for data storage systems which can deliver a large number of continuous data streams. Switching systems on such high bandwidth networks have been or are being developed which can switch from one stream to another and so deliver a continuous stream of data suitable to deliver a video stream to a customer. Currently such streams are generally retrieved from a very large and expansive RAM buffer or from an array of many magnetic discs organized in what is frequently

called a RAID array or a streaming array. Such an approach to data storage requires that the movie or other real time file be "striped" onto the surfaces of many discs so that relatively small sectors of each disc are addressed by a single magnetic head in order to retrieve a very small section of the file continuously.

"Playback" is accomplished by switching from one such segment to another, using buffers to correct for timing differences in order to retrieve the complete file. Such systems require an inordinately large number of discs to store the data because the files are very large and the data density which can be stored on magnetic media are comparatively low. Also the individual components employed in these systems, especially the magnetic media itself, are vulnerable to failure so as a consequence, significant amounts of redundancy must be allowed for, which further increases the number of data storage discs, etc., which in turn increases costs.

Clearly it is preferable if such a system can be implemented using optical recording means which have the benefit of both substantially higher data density and greater playability, both of which factors may be expected to reduce cost and complexity in the data storage devices and, by reducing the number of channels which must be addressed by the networks switch, make it possible to lower overall system costs as well.

Such a system is possible using the counter-translating multiple layer disc approach disclosed above. Specifically, by employing pairs of heads which address respective ones of paired tracks, it yields a uniform data rate per disc rotation from each pair. As a consequence, it is possible to deploy a plurality of heads, for example more than 100 heads, on each disc, each of which addresses a finite number of tracks, typically in the order of 300 tracks, by means of its fine tracking actuator alone. In typical configurations,

such a segment provides 10 sec of data. If a 300 track range is adopted, that means that each head in each pair would address +/-150 tracks for a total of 300 tracks on one side of the disc while its mate would address the corresponding 300 tracks on the other. Tracking of each head in an opposite radial direction would be accomodated by fine positioning by the lens actuators in the two heads so that they undergo contrary translation. The heads of each pair are offset equally from a median radius with each pair covering a different radial band. The net data rate of retrieval of each pair is therefore uniform which facilitates subsequent assembly and transmission of the retrieved data streams.

It should be noted that if such a drive does not make provision to centre the disc to a tolerance of better than +/- 50 microns it may be necessary to employ fine positioning actuators with a radial translation range approximately 50% larger than the usual +/- 300 microns. Alternatively it is possible to employ a spindle/clamper assembly which centers the disc with greater accuracy by employing a sprung tapered spindle. If appropriate, more precise centering may be accomplished by employing a metallic insert in the disc which is more precisely centered relative to the track spiral in the manner commonly employed in magneto-optical discs and drives. Alternatively an automatically adjustable clamper/spindle assembly which improves the centering of the disc sufficiently may be employed.

If necessary or desirable, a coarse positioning mechanism may be employed capable of small excursions on the order of +/- 200 microns.

Assuming each head pair addresses 300 track rotations on each side, then an array of 100 head pairs can address a total of 30,000 tracks per side. Assuming a track pitch of 1.6 microns then such an array of heads can address a total data area on the order of 48,000 microns or 48 millimetres.

As noted earlier, each pair of heads encompasses the same combined track length and, assuming a uniform spatial density is employed in the encoding and marking scheme, each paired rotation will deliver the same amount of data and hence the data capacity of the two-sided disc is 2 times the length of the track at the median radius (C) times the number of tracks (N) or 2CN.

It will be seen that the disposition of a data area at a wider radius on a larger disc will increase the total data capacity of such a system and that the use of more heads disposed over a larger data area can increase the total data capacity and retrieval rate within the limits of the area required to deploy the heads and/or active mirror actuators and the geometric limits imposed by the physical size of the dat disc. For example, assuming the dimensions of compact disc data encoding are employed and that the uniform spatial density employs track pitch of 1.6 microns and a channel bit length of 0.289 micron and the channel code which requires 588 channel bits per data frame and each data frame corresponds to 24 8-bit bytes of data after error correction, then a track pattern formed between radius 132 mm and 148 mm, with a centre radius of 140 mm will be composed of 10,000 tracks on each side with the sum of the track lengths of each matched pair of tracks equalling 1,759,296 microns in length, and the entire track length 17,592,960,000 microns in length which in turn corresponds to 60,875,294,117 channel bits or 103,529,411 data frames or 2,484,705,882 bytes of data. This may also be expressed as 6,087,529 channel bits per revolution, or 10,352 data frames per revolution or 248,470 bytes per revolution. This corresponds to 1,987,760 megabits/revolution.

In the same manner, it can be shown that if the data areas are centered at a radius of 124 mm and the data area extends from an inner radius of 100 mm to an outer radius of 148 mm, such a disc can encode 30,000

tracks on each side for combined total data capacity of more than 6.6 GigaBytes. In this case, the data rate may be shown to be 220,073 bytes per revolution.

It follows that a continuous video stream on the order of 4 mb/s may be delivered from a disc such as that cited in the first example if the disc is scanned at a rotational rate only slightly higher than 2 rps and the in second example by a rotational rate of about 2.27 rps.

It is possible to scan such two-sided discs at rotational rates as high as 64 rps and rates up to 30 rps may be considered within the operating parameters of the lens actuators employed in conventional commercial optical drives and even home LaserVision players. If the data disc is spun at 30 rps, it may be seen that each of the 100 head pairs can read data at a very high rate when compared with the requirement to deliver a 4 mb/s data stream. In the case of the first example, this data rate is approximately 14.9 times faster while even the slower second case is more than 13 times as fast.

Such fast data streams can be divided in a number of ways into discrete slower streams which more precisely meet the requirement of delivering a continuous compressed data stream to an On Demand network. for the purposes of the following discussion the rotational rate is presumed to be one which will deliver a data rate of 40 megabits per second (mbs) from each matched pair of heads.

In one arrangement of data, each band addressed by a head pair can contain a number, for example 10, of interleaved data streams so that each pair then delivers 10 streams of data at 4 mbs for a total of 1,000 streams form all 100 head pairs. Such a configuration employing 1,000 data streams may be employed to deliver 1,000 each 9 seconds apart from a single optical disc. This can provide for example 1,000 start times 9 seconds apart. Alternatively, it is possible to make machines based on this same principle so that each of 9 machines, each with

1,000 streams, deliver 1,000 simultaneous data streams for a total of 9,000 simultaneous streams of the same movie. This corresponds for example to one stream for every second of a 2-1/2 hour movie.

For the purposes of the discussion to follow, it is assumed that a multiple drive array of 10 machines may deployed with data files which effectively contain 10 copies of a digital file to be delivered such as a video movie.

There are many possible file architectures by which the data may be formed into interleaved files on the disc. As such a massively parallel approach assumes more than one copy of each component of the data files so it is possible to configure the data as being replicated on more than one disc or as being replicated in a sequential pattern employing interleaving the same data stream in the same file on a delay basis. Either approach and any combination of these approaches may be employed to satisfy the demands of this application. It is also possible to tailor the file architecture to take advantage of this redundancy in order to reduce the error correction and encoding requirements of such data compression systems as MPEG (the international standard established by the so-called Motion Pictures Experts Group).

For the purposes of this application, preferentially each pair addresses an interleaved file which interleaves the same file portion. Assuming a disc rotations rate of 30 revolutions per second, then the 300 tracks which can be addressed by each head can be scanned in 10 seconds. It may be desirable to scan these tracks in slightly less than 10 seconds in order to allow for a period on the order of 20 milliseconds to reposition the head to the start of the pattern and an additional 30-40 milliseconds to reacquire the data stream. Such repositioning may be facilitated by employing unique marking patterns at the boundaries of each track pattern

on the disc. Such marking patterns can be created in a number of ways including but not limited to unique data marks comparable to the so-called "flags" employed in the Compact Disc system or even highly detectable spiral track areas forme of unmodulated grooves.

The 10 second scanning period then captures the same second of data 10 times, however, the data is so interleaved that when it is de-interleaved it yields 10 distinct copies of the data each of which is delayed relative to the preceding stream by one second. In this manner, the interleaved file may be read at 40 megabits per second during each scanning period of one second while demodulation and de-interleaving circuits deliver 10 de-interleaved files of 4 mb each from the buffers associated with each de-interleaved stream. In other words, as 300 tracks are read in 10 seconds, the data is streamed out to deliver 10 streams of 4 mbs with start times staggered one second apart over the 10 second period. This amounts to a series of 10 staggered but otherwise identical data streams each running in a continuous loop.

By this means each head can deliver 10 seconds of the real time file and an array of 100 heads can accomodate 1,000 seconds of programming material. AS there are 10 copies of each second of programming material and this material is interleaved, during each 10 second scanning period each pair of heads delivers 10 staggered streams each containing 10 seconds of program material.

It will be readily understood that this approach effectively employs a 10-fold data storage requirement and may be accomplished by employing 10 such disc/drives arrangements, each with 100 head pairs.

Any single stream from a pair of heads then delivers the 10 seconds of program material it contains in sequence with appropriate timing. similarly, the next

10 seconds of the program can be delivered by addressing one of the 10 de-interleaved streams which encode it.

A data streaming means may be implemented by employing a FIFO buffer, which fills alternately with a data stream corresponding to first one 10 second period and then the next. And it may be readily seen that the 10 x 10-second staggered streams present ample opportunity to always keep the buffer full. The data stream being delivered to the customer may be assembled with reference to a crystal clock by various means well known to prior art. Typically, it will require on the order of 900 such filling and delivery operations in order to deliver an entire 2-1/2 hour movie.

While in most cases it is unlikely to be desirable to synchronize the buffers across the system to a single system clock, such a requirement may be desirable in very large networks in which data streams are switched by massively parallel computer switches. Such synchronization of parallel streams may be accomplished by conventional means well known to prior art and specifically with provision to reacquire synchronization frequently. Alternatively, synchronization stability may be enhanced by injecting a pseudo-periodic (i.e. chaotic) signal into the clock signal in the manner discussed in Pecora & Carroll "Driving Systems with Chaotic Signals" (Phys. Rev. A, vol. 44, pp. 2374-2383, August 1991) and in related ways. Once the system buffers have been synchronized in a stable or at least reliable manner, it is possible to deliver continuous streams of data each comprising an entire file such as a video movie by switching from one stream to another in sequence and it is likewise possible to perform the equivalent of virtually instantaneous fast forward or rewind by switching to the appropriate streams. It is likewise possible to scan forward or back in an abbreviated fashion by skipping time streams.

The ability of such systems to deliver data at a rate which is higher than the data stream which must be delivered out of the FIFO or switch can be used to accumulate the small amount of time required when the head pairs reach the end of their spiral section and must be re-addressed to the start of that spiral. However, it is also possible undertake such repositioning by employing a data buffer with appropriately designed delay. In either case, the data stream can be delivered continuously from buffers at the correct clock rate.

I claim:

1. An optical data carrier having information arranged in a pair of spiral tracks spaced from one another along the optical axis of said carrier, said tracks being of opposite hand.

2. An optical data carrier according to claim 1 wherein said information in each track is arranged with a uniform spatial density.

3. An optical data carrier according to claim 1 wherein each of said tracks are at least partially reflective to incident radiation.

4. An optical data carrier according to claim 3 wherein at least one of said tracks is partially transmissive to permit incident radiation to be transmitted to another of said tracks underlying said one track.

5. An optical playback apparatus comprising a data carrier having information arranged in a pair of spiral tracks spaced from one another along the optical axis of said carrier with said tracks being of opposite hand and an optical head movable relative to said carrier to interrogate said carrier with incident radiation and to read information from at least one of said tracks.

6. An optical playback apparatus according to claim 5 wherein said head is selectively operable to cause said incident radiation to impinge upon one of a plurality of said tracks to permit sequential reading of information from a pair of tracks.

7. An optical playback apparatus according to claim 6 wherein a buffer is provided to retain

information and output such information as said head moves from one track to another.

8. An optical playback apparatus according to claim 5 wherein a pair of optical heads are provided to read respective ones of said tracks.

9. An optical playback apparatus according to claim 8 wherein said heads interrogate respective tracks simultaneously.

10. An optical playback apparatus according to claim 9 wherein information read from each of said tracks is demodulated to a common data rate.

11. An optical playback apparatus according to claim 10 wherein information read from each track is combined in a common data stream.

12. An optical playback apparatus according to claim 10 wherein information is recorded at a uniform spatial density, said apparatus including reference timing tracks to provide an indication of timing at each radius and permit demodulation of information to a common data rate.

13. An optical playback apparatus according to claim 12 wherein said reference timing tracks are spaced from said carrier and read by respective ones of said heads to demodulate information being read thereby.

14. An optical playback apparatus according to claim 10 wherein said information is recorded at a uniform spatial density and the position of said head relative to said carrier is monitored to regulate the demodulation of information.

15. An optical playback apparatus according to claim 14 wherein a master clock drives a voltage controlled oscillator to determine the demodulating clock rate and a position signal factors said master clock signal in accordance with the relative position of said head and said carrier.

16. An optical playback apparatus according to claim 15 wherein the data rate of said combined data stream is compared to said master clock and the demodulating clock of each head adjusted in accordance with said comparison.

17. A method of retrieving information recorded on a data carrier in a pair of spiral tracks of opposite hand comprising the steps of interrogating each of said tracks simultaneously with respective read heads to obtain respective data streams, demodulating each of said streams to a common data rate and combining said streams into a common data stream.

18. A method according to claim 17 wherein said information is recorded at a uniform spatial density and said method includes monitoring the relative position of said head and carrier to regulate said demodulation.

19. A method according to claim 18 wherein a separate tuning track is monitored to adjust the demodulation of said data stream.

20. A method according to claim 18 wherein a master clock provides a demodulation signal and the relative position of said carrier and read head is used to modify the master clock.

21. A method according to claim 20 wherein said common data stream is monitored and the data rate thereof

compared to said master clock, said demodulation being adjusted in accordance with such comparison.

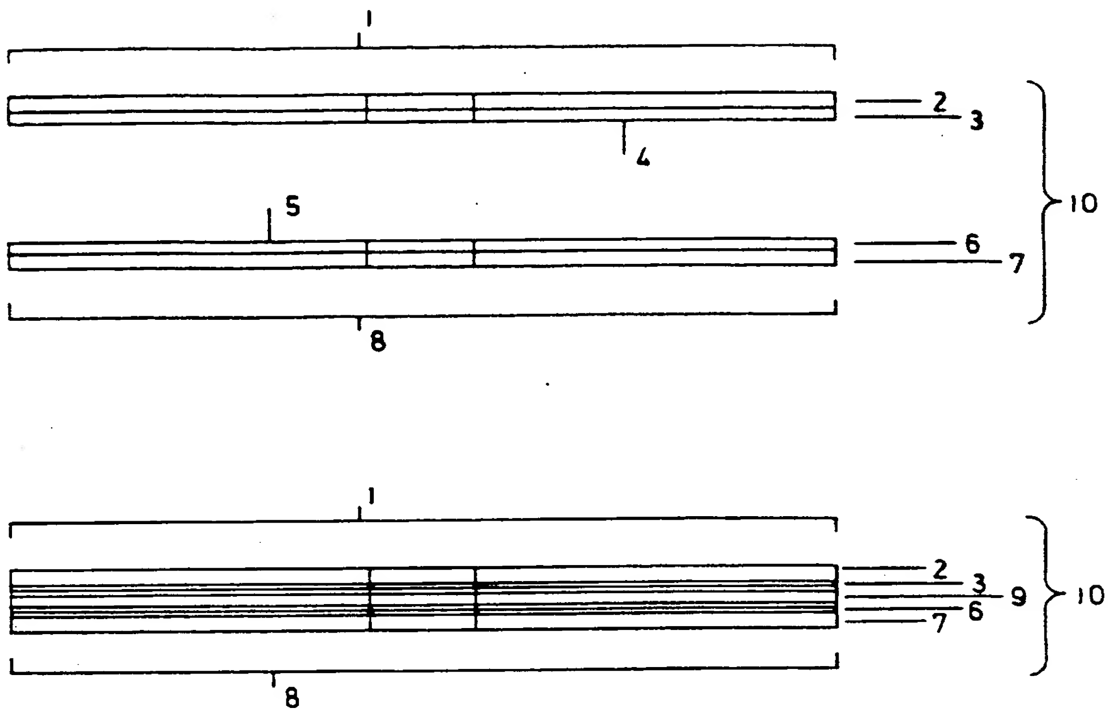

FIG. 1

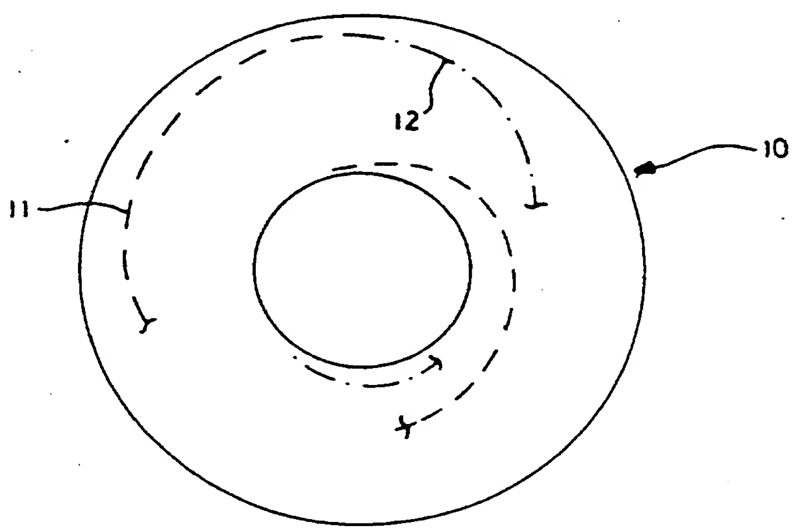

FIG. 2

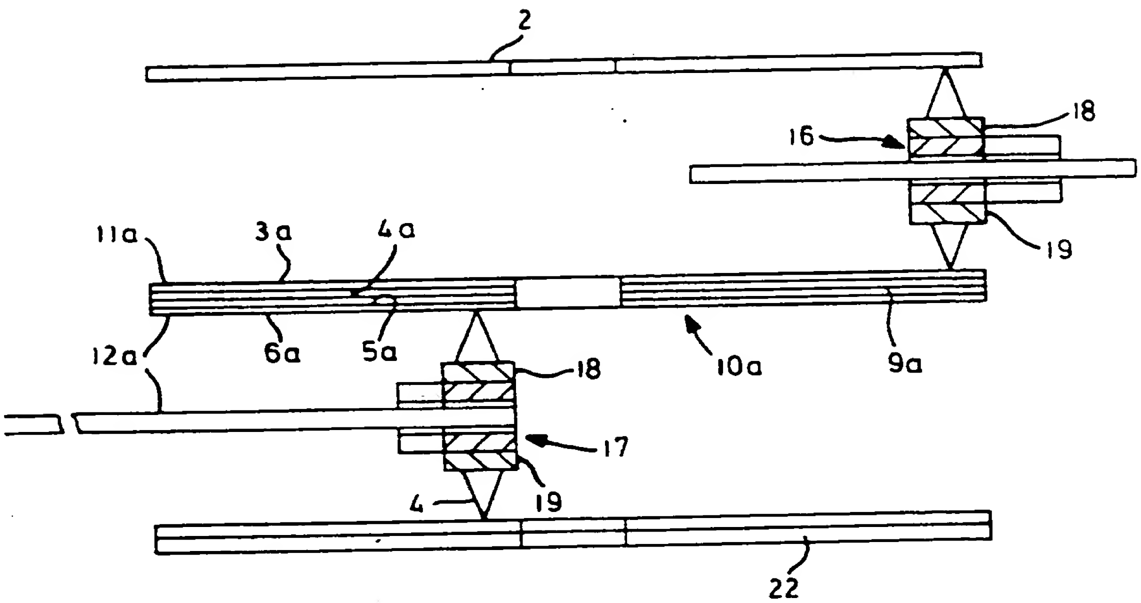

FIG. 3

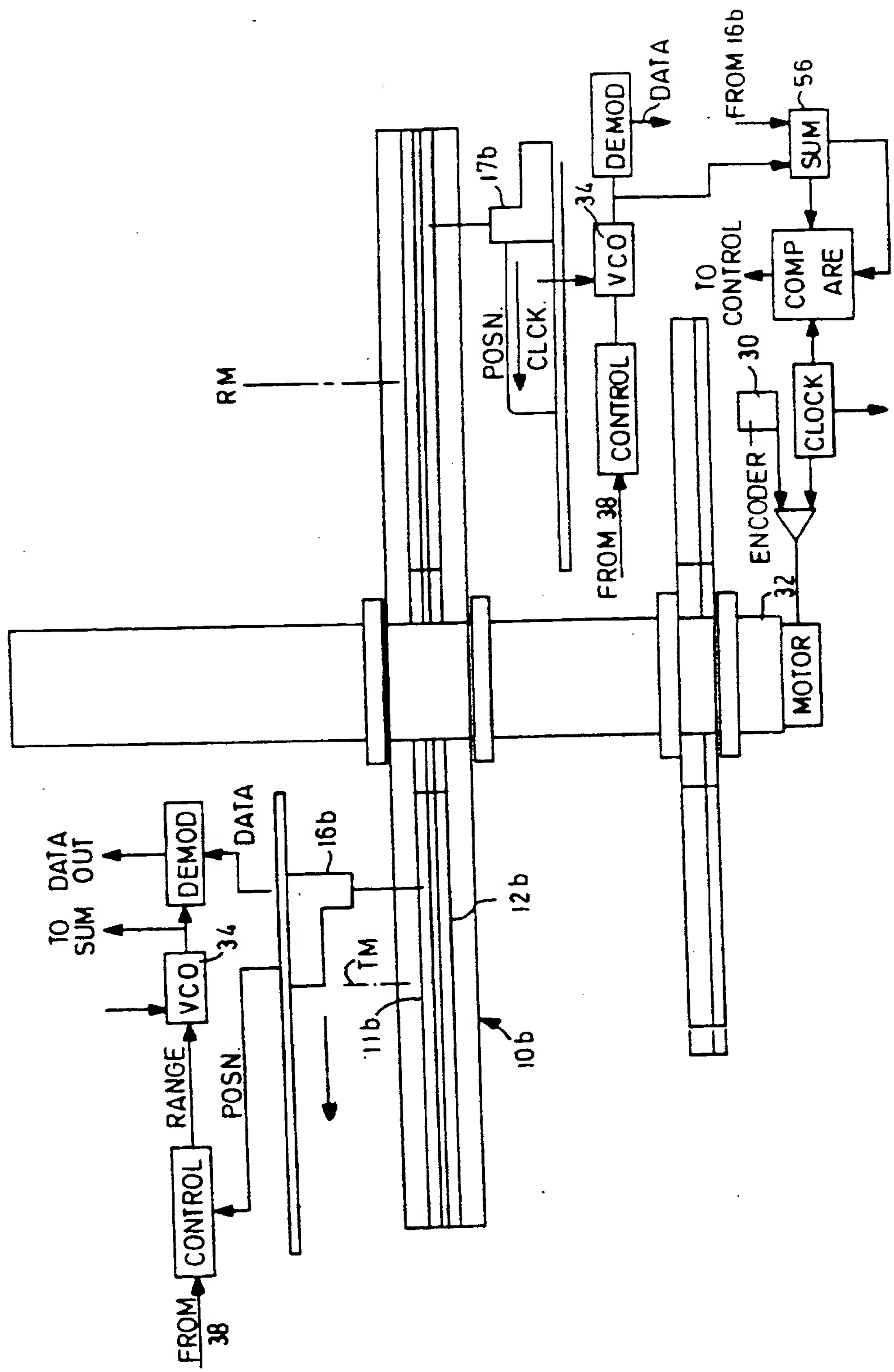
RM
17b
34
DEMOD
DATA
FROM 16b
56
SUM
VCO
COMP ARE
TO CONTROL
POSN.
CLCK.
CONTROL
FROM 38
30
ENCODER
CLOCK
32
MOTOR
TO SUM
DATA OUT
DEMOD
DATA
16b
34
VCO
RANGE
POSN.
CONTROL
FROM 38
TM
11b
12b
10b

FIG. 4

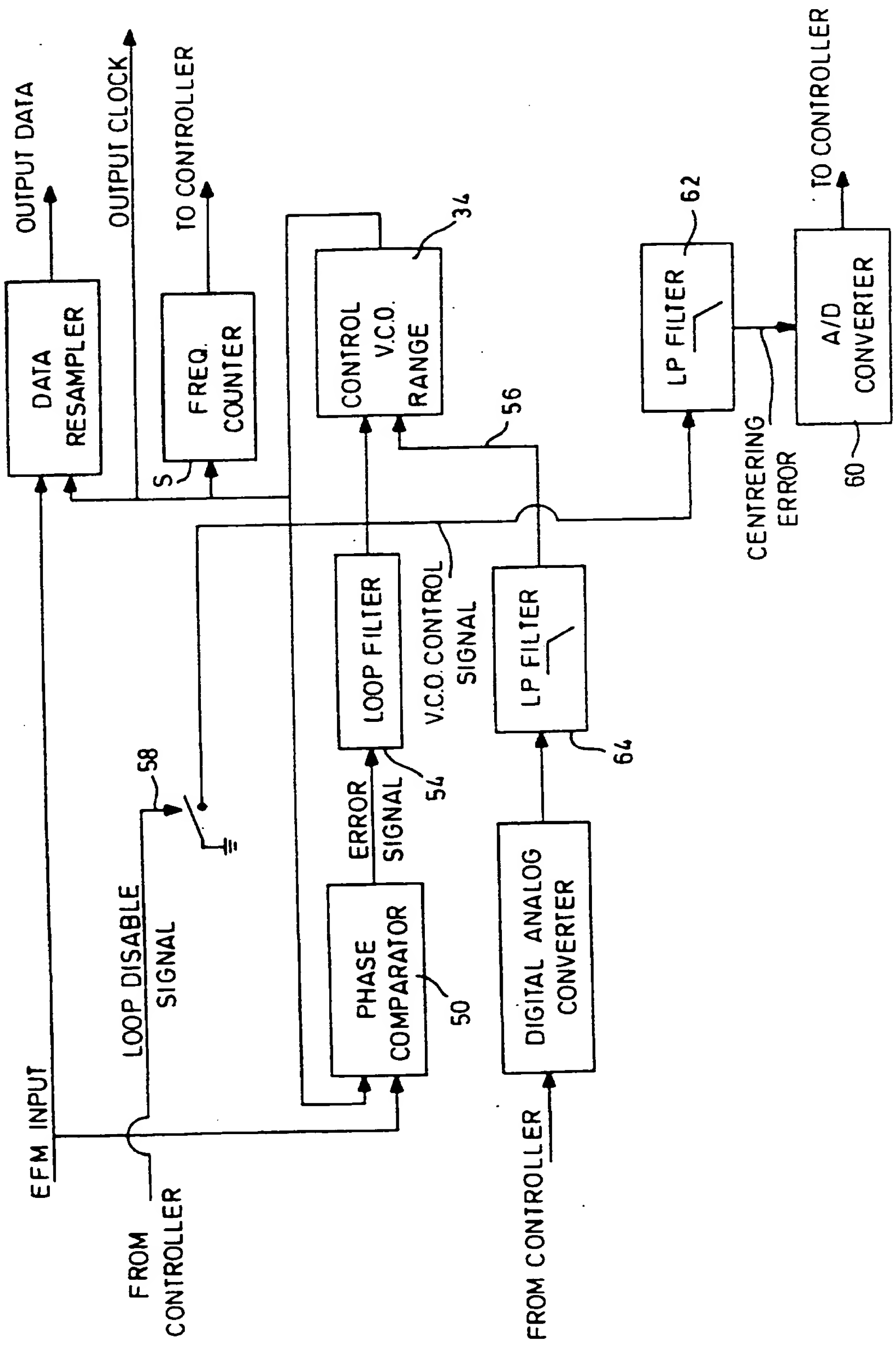
OUTPUT DATA
OUTPUT CLOCK
TO CONTROLLER
TO CONTROLLER
DATA RESAMPLER
FREQ. COUNTER
CONTROL V.C.O. RANGE
34
LP FILTER
62
A/D CONVERTER
60
CENTRERING ERROR
56
S
V.C.O. CONTROL SIGNAL
LOOP FILTER
LP FILTER
64
54
58
ERROR SIGNAL
LOOP DISABLE SIGNAL
PHASE COMPARATOR
50
DIGITAL ANALOG CONVERTER
EFM INPUT
FROM CONTROLLER
FROM CONTROLLER

FIG. 5

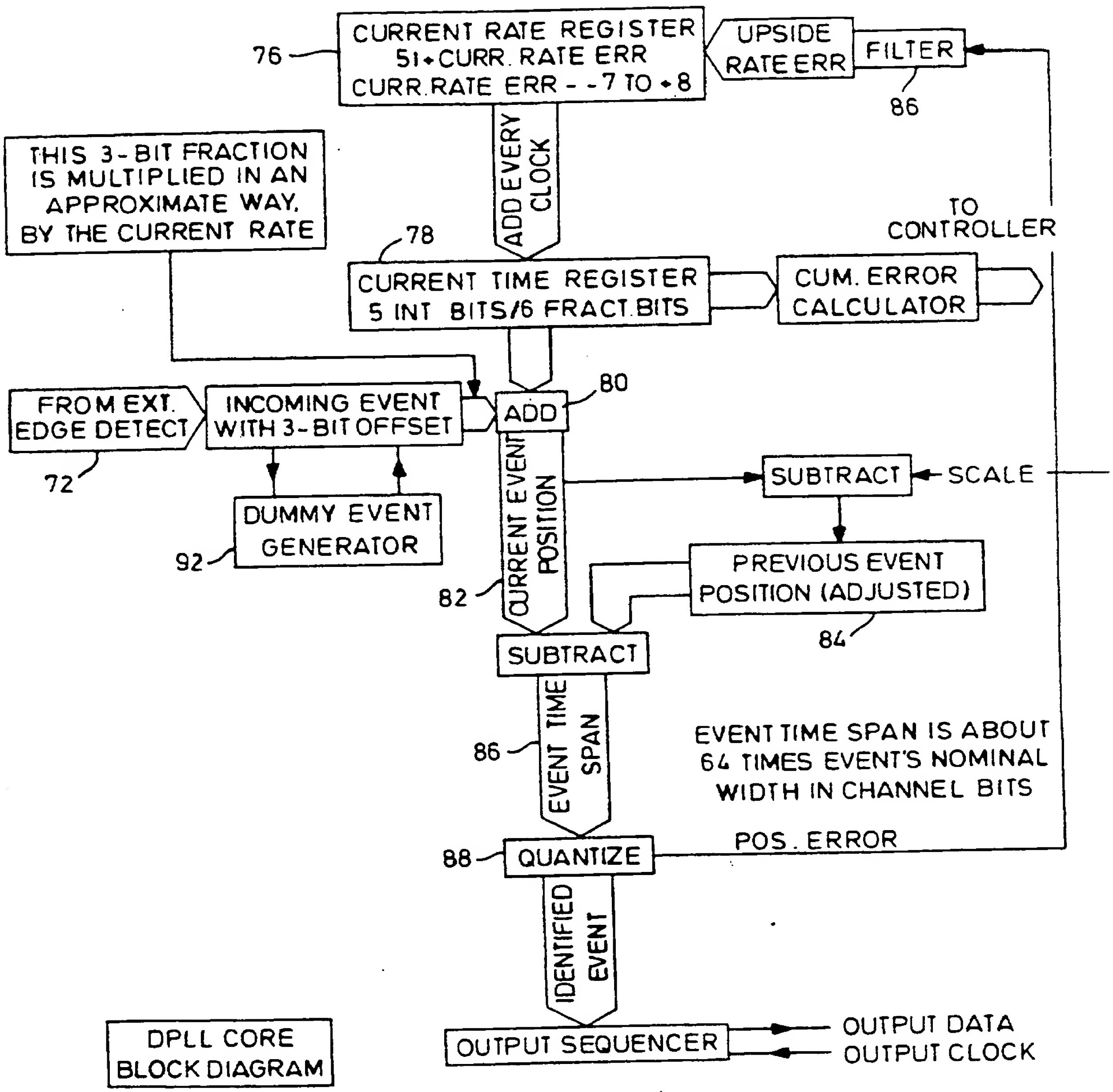
CURRENT RATE REGISTER
51+CURR. RATE ERR
CURR.RATE ERR - -7 TO +8
76
UPSIDE
RATE ERR
FILTER
86
THIS 3-BIT FRACTION IS MULTIPLIED IN AN APPROXIMATE WAY, BY THE CURRENT RATE
ADD EVERY CLOCK
TO CONTROLLER
78
CURRENT TIME REGISTER
5 INT BITS/6 FRACT.BITS
CUM. ERROR CALCULATOR
80
FROM EXT. EDGE DETECT
INCOMING EVENT WITH 3-BIT OFFSET
ADD
72
CURRENT EVENT POSITION
SUBTRACT
SCALE
DUMMY EVENT GENERATOR
92
PREVIOUS EVENT POSITION (ADJUSTED)
82
84
SUBTRACT
EVENT TIME SPAN
86
EVENT TIME SPAN IS ABOUT 64 TIMES EVENT'S NOMINAL WIDTH IN CHANNEL BITS
POS. ERROR
88
QUANTIZE
IDENTIFIED EVENT
DPLL CORE BLOCK DIAGRAM
OUTPUT SEQUENCER
OUTPUT DATA
OUTPUT CLOCK

FIG. 7

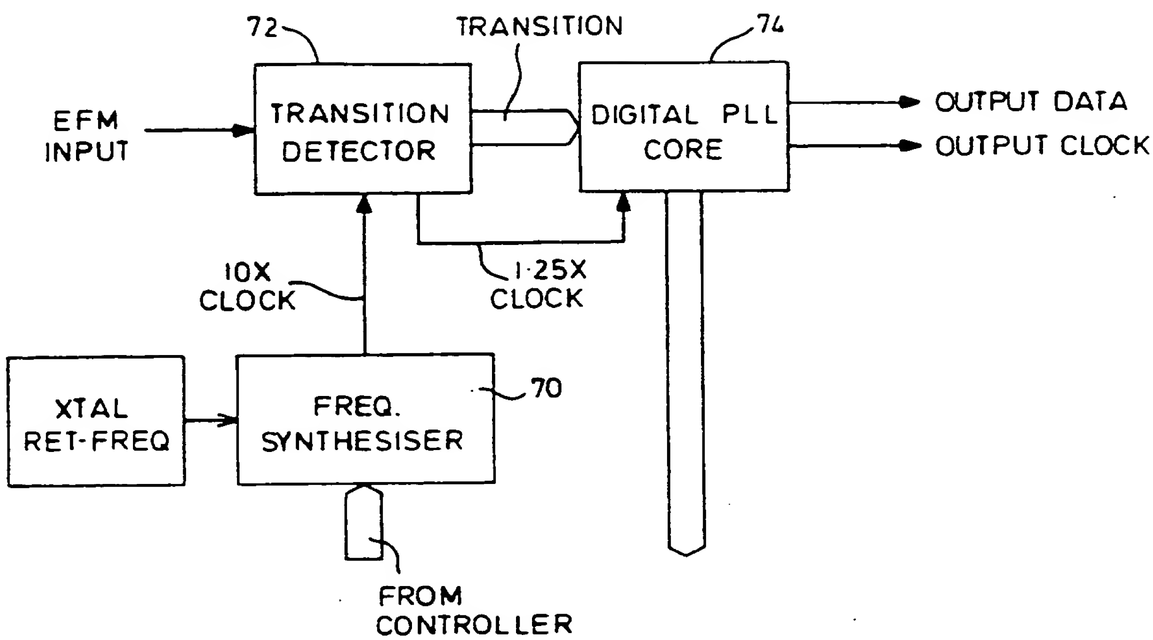
72
TRANSITION
74
EFM
INPUT
TRANSITION
DETECTOR
DIGITAL PLL
CORE
OUTPUT DATA
OUTPUT CLOCK
10X
CLOCK
1·25X
CLOCK
XTAL
RET-FREQ
FREQ.
SYNTHESISER
70
FROM
CONTROLLER

FIG. 6

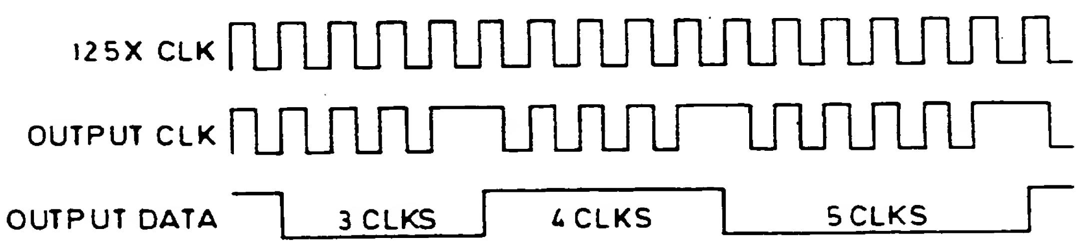
125X CLK
OUTPUT CLK
OUTPUT DATA
3 CLKS
4 CLKS
5 CLKS

FIG. 8

INTERNATIONAL SEARCH REPORT

Inter   nal Application No
PCT/CA 95/00530

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G11B7/007 G11B7/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G11B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	PATENT ABSTRACTS OF JAPAN vol. 013 no. 377 (P-922) ,22 August 1989 & JP,A,01 130375 (NEC CORP) 23 May 1989, see abstract ---	1,5, 8-11,17 12,13, 18,19
Y	GB,A,2 231 707 (DEWAR PRODUCTIONS INC) 21 November 1990 see page 12, line 3 - line 6; figure 5B see abstract & US,A,5 303 215 (S. DEWAR & M. BREYFOGLE) cited in the application ---	12,13, 18,19
X	PATENT ABSTRACTS OF JAPAN vol. 013 no. 087 (P-835) ,28 February 1989 & JP,A,63 268160 (HITACHI LTD) 4 November 1988, see abstract --- -/--	1,2,5,6, 8

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 January 1996	08.02.96

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Holubov, C

INTERNATIONAL SEARCH REPORT

Inter   nal Application No
PCT/CA 95/00530

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 517 490 (IBM) 9 December 1992 see column 7, line 40 - line 56; figure 3	1,3-6
X	GB,A,2 091 028 (PHILIPS NV) 21 July 1982 see page 2, line 23 - line 45	1,3
X A	US,A,3 999 009 (BOUWHUIS GIJSBERTUS) 21 December 1976 see the whole document	1,5,6 4
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